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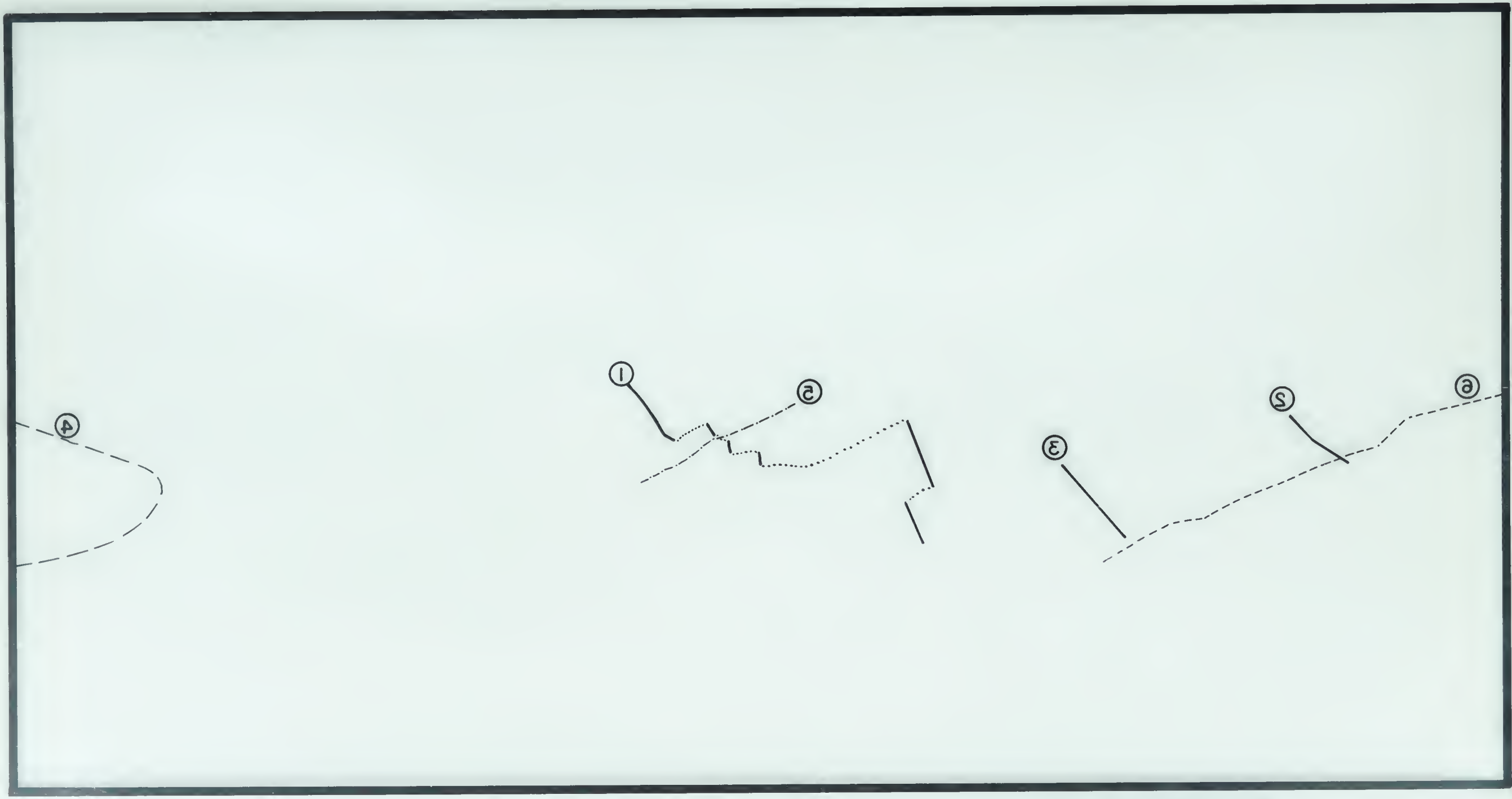
Pyramid and Kinross Mountains

1. Pyramid A Type Section
2. Kinross Supplementary Type Section
3. Pyramid B Supplementary Section
4. — — —Trace Pyramid Thrust Fault
5. -·-·-·-Approximate Contact Jasper - Formation A
6. ------Approximate Contact Miette-Jasper



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Pyramid and Kinross Mountains

Thesis
1964 (F)
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THE UNIVERSITY OF ALBERTA

THE JASPER FORMATION, JASPER, ALBERTA

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY

by

ALFRED JOHN AKEHURST, B.E.

EDMONTON, ALBERTA

May, 1964

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Jasper Formation, Jasper, Alberta," submitted by Alfred John Akehurst, B.E., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Rocks of the Jasper Formation are exposed in the vicinity of Jasper, Alberta, in the hanging wall of the Pyramid thrust fault. They are underlain by dominantly argillaceous strata of the Miette Formation, probably Precambrian in age, and conformably overlain by quartzites of Formation A, which is Cambrian in age. Although they are non-fossiliferous, they have been assigned to the Cambrian on lithological grounds. The type section is located on the eastern slopes of Pyramid and Kinross mountains. The formation, some 1500 to 1700 feet in thickness, is divided into two members. The lower member, of variable thickness from 280 to 420 feet, is composed of argillites, siltstones, and feldspathic and conglomeratic sandstones; its basal beds are apparently conformable with the underlying Miette strata. The upper member is composed largely of feldspathic and conglomeratic sandstones, with a distinctive cobble conglomerate unit, 120 feet thick, near the middle; its assigned thickness is 1240 feet, although the contact with the overlying quartzites of Formation A is gradational. The latter formation comprises clean well sorted quartzites, feldspathic in the lower beds, grading upwards into feldspar-free orthoquartzites; an argillaceous sequence, 200 feet thick, occurs 700 feet above the base. The Jasper Formation is thought to have been deposited in marine waters of shallow depth.

The rocks of the Jasper Formation and Formation A exposed on Pyramid and Kinross mountains form part of the northeastern limb of the Jasper anticlinorium, and have been folded into broad, simple folds. Those to the east of Pyramid Lake, however, in a similar structural position, have suffered much more intense deformation due to their proximity to the Pyramid thrust fault. Folding, and both transcurrent and thrust faulting, are present. The trend of the thrust faults suggests that anticlockwise rotation has taken place along the Pyramid thrust.

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Permission to take samples of the rocks in Jasper Park was kindly afforded by Mr. J.R.B. Coleman, Director of the National Parks Branch of the Department of Northern Affairs and Natural Resources.

TABLE OF CONTENTS

	Page
ABSTRACT	i
ACKNOWLEDGMENTS	ii
INTRODUCTION	1
STRATIGRAPHY	1
Introduction	1
The Jasper Formation	3
General	3
Lower Member	4
Upper Member	7
Formation A	11
General	11
Age	11
Depositional Environment	12
Provenance	13
STRUCTURE OF THE PYRAMID LAKE MAP-AREA	15
Introduction	15
Faulting and Folding	16
Jointing and Fracturing	17
Discussion	17
METAMORPHISM AND VEINING	19
CONCLUSIONS	21
REFERENCES CITED	23
APPENDIX A	24
Thin Section Descriptions	24

LIST OF PLATES, FIGURES AND TABLES

PLATES:

	Pyramid and Kinross Mountains, Jasper National Park, Alberta.	Frontispiece

FIGURES:

Figure 1	Map of the Jasper Area, showing the locations of the type and supplementary sections of the Jasper Formation, the Pyramid Lake map-area, the Jasper anticline, and the Pyramid thrust fault.	Page 2
Figure 2	Stratigraphic Correlation	Page 6
Figure 3	Outcrops Lithology and Bedding Attitudes	Pocket
Figure 4	Tectonic Data Joints and Fractures	Pocket
Figure 5	Structure and Stratigraphy	Pocket
Figure 5a	Structure Sections	Pocket

TABLES:

Table 1	Table of Formations	Page 3
Table 2	Pyramid-Kinross Type Section (abridged)	Page 5
Table 3	Pyramid A Type Section Kinross Supplementary Type Section Pyramid B Supplementary Section	Pocket
Table 4	Heavy Accessory Mineral Suites	Page 8

I INTRODUCTION

The Main Ranges of the Canadian Rocky Mountains expose Precambrian and Palaeozoic sedimentary and low-grade metamorphic rocks. The Cambrian Jasper Formation is exposed extensively in the vicinity of Jasper, Alberta. This formation was studied, for the purposes of this thesis, in the Pyramid Lake Map-area, 2 1/2 miles north of Jasper townsite, and on the eastern slopes of Pyramid and Kinross mountains (Figure 1).

Field mapping was carried out during the summer of 1961 as part of a programme of detailed mapping of Precambrian and Lower Cambrian rocks undertaken by graduate students under the direction of Dr. H.A.K. Charlesworth.

II STRATIGRAPHY

Introduction

The Precambrian and Lower Cambrian rocks of the Jasper area have been variously designated. Walcott (1913, p. 340) used the term Miette in referring to grey sandstones and argillites outcropping in the Miette River valley west of Jasper. These were stated to unconformably underlie the Cambrian and to be Precambrian in age. Allan et al. (1932, p. 321) described a succession of similar rocks exposed below Lower Cambrian quartzites near the foot of Pyramid Mountain; these they termed the "Jasper series". More recently, Mountjoy (1962) has elevated the term Miette to group status, redefining it to include all the recessive strata exposed beneath cliff-forming quartz sandstones and quartzites belonging to the Gog Group. Mountjoy referred the Miette to the Precambrian and the Gog to the Cambrian.

More detailed work by Charlesworth et al. (1960, 1961) has led to the recognition of five distinct mappable units within the Precambrian and Lower Cambrian succession. They divided the Precambrian succession into three formations, the term Miette being retained for the youngest, and the Cambrian into two (see Table 1).

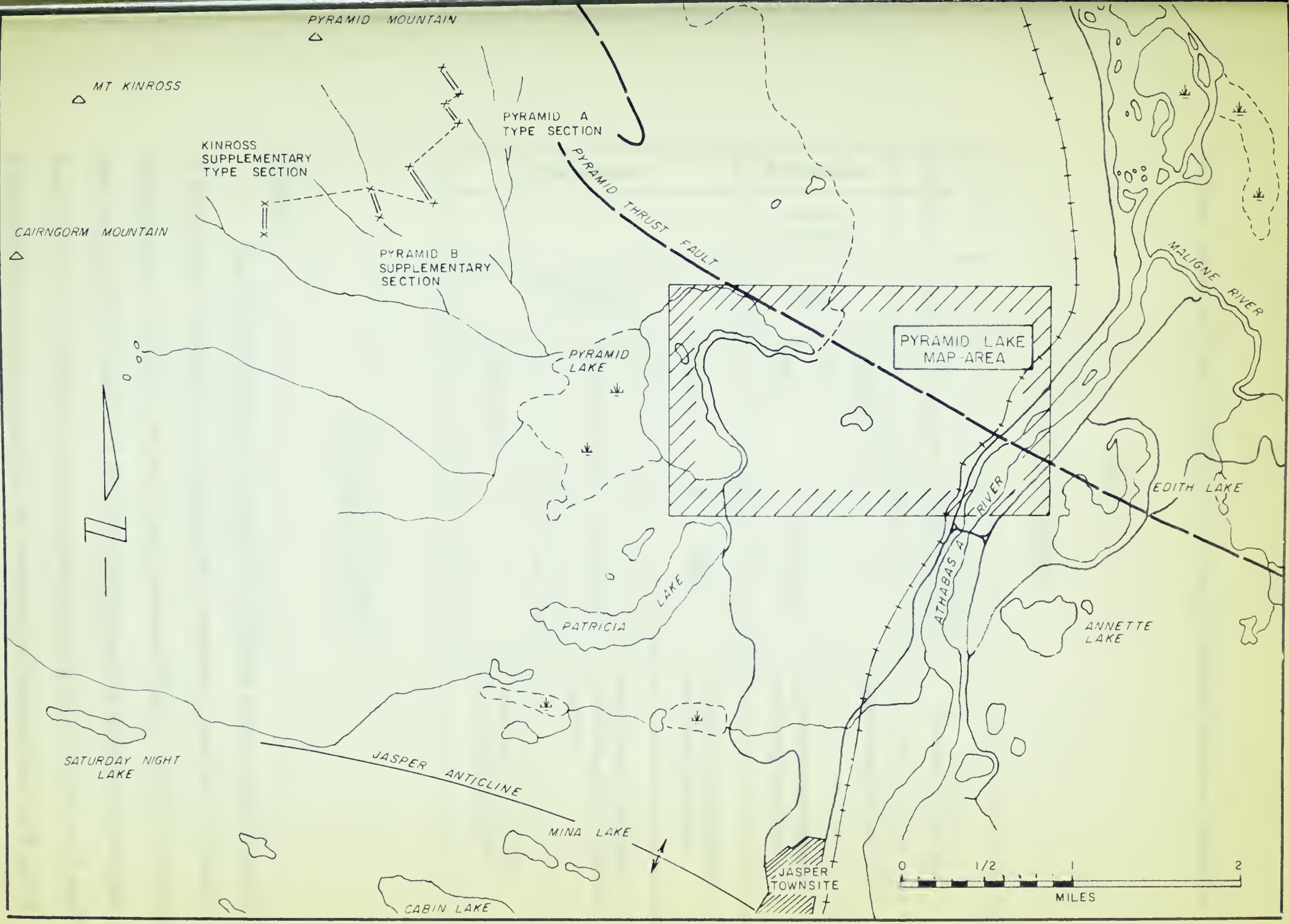

Figure 1

Map of the Jasper area, showing the locations of the type and supplementary sections of the Jasper Formation, the Pyramid Lake map-area, the Jasper anticline, and the Pyramid thrust fault.

The term Jasper has been retained for the lower of the two Cambrian formations.

TABLE I

Table of Formations

Era	Epoch	Group	Formation	Approximate Thickness (Feet)	General Lithology
Palaeozoic	Lower Cambrian	Gog	Formation A	?	Quartzites and argillites
			Jasper	1500-1700	Feldspathic sandstones and conglomerates
Proterozoic		Windermere (Miette)	Miette	4000	Argillites, sandstones and conglomerates
			Old Fort Point	1200-1500	Argillites, siltstones, limestones and limestone breccias
			Formation B	?	Sandstones, argillites and conglomerates

The Jasper Formation

General

The Jasper Formation, some 1500 to 1700 feet thick, consists essentially of well-sorted, feldspathic and conglomeratic sandstones, pebble- and cobble-conglomerates, with thin interbeds of argillaceous siltstones. It may be distinguished from the overlying Formation A by poorer sorting and the absence of quartzites, and from the underlying Miette Formation by better sorting and the scarcity of argillites. Collet (1932) reported the presence of carbonates on the east flank of Pyramid Mountain at a stratigraphic level somewhere near the contact of what are referred

to here as the Jasper Formation and Formation A. However, no carbonates have been found by the writer at this stratigraphic level, so it appears likely that the carbonates observed by Collet are either in the footwall of the Pyramid thrust fault, or occur as a fault slice within the fault zone. Their age and stratigraphic position are therefore uncertain. Conglomeratic and quartzitic sandstones, similar to those of the Jasper Formation, together with interbedded algal carbonates, outcrop near the base of Signal Mountain across the Athabasca valley to the southeast. The stratigraphic position of these rocks is questionable, since they are bounded by faults.

On the eastern slopes of Pyramid and Kinross Mountains the Jasper is apparently conformable with, and grades into, Formation A and the Miette Formation, respectively. The conformable nature of the Miette-Jasper contact is further suggested by (1) the occurrence of argillites in the basal part of the otherwise arenaceous Jasper, and of sandstones at the top of the otherwise argillaceous upper Miette, and (2) the occurrence of plagioclase (common in the Miette) in the basal Jasper and its absence from the higher beds of the formation.

The composite stratigraphic section of the Jasper Formation exposed on Pyramid and Kinross mountains (Tables 2 and 3) has been selected as the type section. The formation may be conveniently divided into two members.

Lower member

The marked variations in thickness and lithology of this member, attributable to facies changes, are depicted in Figure 2 and Table 3. In the Pyramid Lake map-area the argillite-siltstone-sandstone sequence comprising the lower member forms a distinctive mappable unit (Figure 5).

TABLE 2

Pyramid-Kinross Type Section (abridged)

Formation	Member	Thickness (Feet)	General Lithology
Formation A		930+	Well sorted quartzite, and feldspathic and quartzitic sandstone; some argillite and siltstone near top of section
Jasper	Upper	640	Pebble conglomerates and pebbly feldspathic sandstones
		120	Pebble and cobble conglomerates
		480	Conglomeratic and feldspathic sandstones
	Lower	280 to 420+	Argillites and siltstones grading downward to pebbly feldspathic sandstones
Miette		60+	Silty argillites with interbedded siltstones

The conglomeratic and feldspathic sandstones are lenticular, individual beds varying in thickness from 2 to 5 feet. They are largely composed of subrounded to subangular granules and pebbles, with occasional rounded pebbles up to 10 mm in diameter. Although quartz is the dominant constituent, accounting for about 60 per cent of the rock volume, quartzite rock fragments (20 per cent), and microcline feldspar (10 per cent), are commonly present. The microcline feldspar content locally approaches 40 per cent in some of the higher beds. Plagioclase and chlorite grains occur sporadically. The matrix, about 10 per cent of the rock volume, consists largely of finely divided sericite.

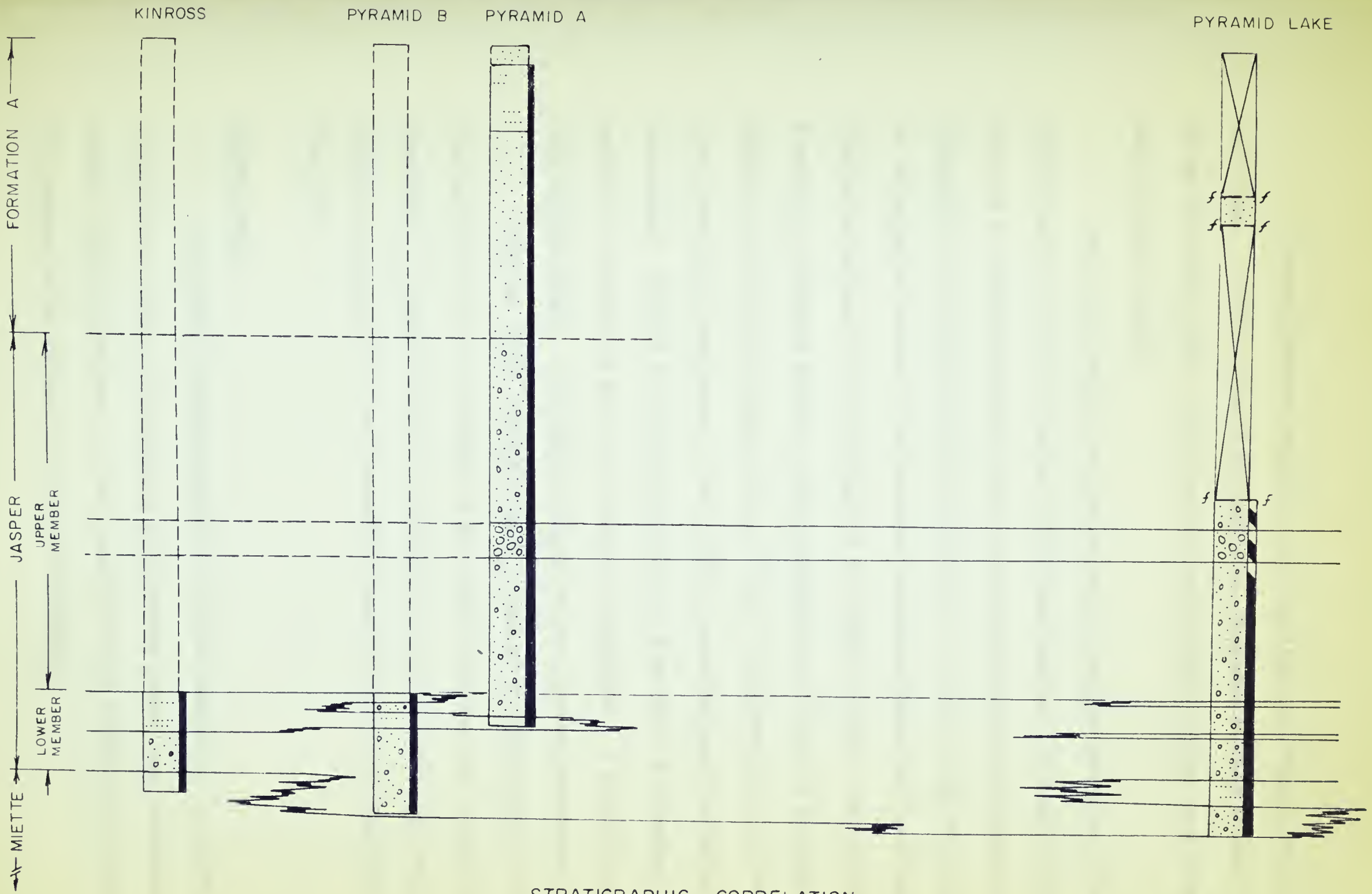
KINROSS
PYRAMID B
PYRAMID A
PYRAMID LAKE
FORMATION A
JASPER
UPPER MEMBER
LOWER MEMBER
MIETTE
STRATIGRAPHIC CORRELATION
SCALE: HOR. 1" = 2000'
VERT. 1" = 500'
LEGEND
CONGLOMERATIC SANDSTONE
NOT PRESENT
COBBLE CONGLOMERATE
NOT MEASURED
FAULT
ARGILLITE, SILTSTONE
MEASURED

Figure 2

In the argillaceous sequences, silty argillites and siltstones are the chief rock types. The silty nature of the argillites is indicated by their content: about 50 per cent quartz grains, 10 per cent microcline feldspar grains, and 40 per cent matrix (mostly chlorite).

Most quartz pebbles and granules exhibit undulose extinction. The dark green chlorite grains are locally abundant in the lower beds; some of these grains were observed in intimate association with highly altered plagioclase feldspar and are, presumably, an alteration product of the latter. It is worth noting that, except for its infrequent occurrence in the lowermost arenaceous beds of the lower member, plagioclase feldspar is virtually absent in the Jasper Formation. Microcline feldspar, however, is commonly present, usually as pebbles up to 10 mm in diameter, with bright, fresh-looking cleavage surfaces. Silica, in the form of quartz which often forms conspicuous overgrowths, is the principal cementing agent; welded grain contacts are common. Siderite in concentrations of up to 5 per cent, is a common, though sporadic, constituent of both the siltstones and sandstones. It is usually associated with altered feldspar. Phenoclasts of argillite are of common occurrence.

Williams (1958) studied the heavy accessory minerals present in a sample from the basal beds of the lower member of the Jasper Formation near Pyramid Lake. He found them to consist principally of tourmaline, including indicolite, and zircon; granitic and pegmatitic types of tourmaline were dominant in the tourmaline suite (Table 4).

Upper member

This member is distinguished from the lower member by the relative scarcity of argillaceous beds, by the presence of distinctive cobble conglomerates near the middle, and by the absence of chlorite and chloritized feldspar grains in the sandstones. The member can be divided into three units (Table 2).

TABLE 4

Heavy Accessory Mineral Suites

	PC 6[1] Non-magnetic at 1.0 Amp.	PC 6[1] Magnetic at 1.0 Amp. Treated with HCl	P 37[2] Non-magnetic at 1.0 Amp.	P 217[3] Magnetic at 1.0 Amp. Treated with HCl
Tourmaline I	1	6	5	5
Tourmaline II		7	4	4
Tourmaline III		2	5	7
Tourmaline IV				
Rutile	1		2	3
Apatite	4		2	
Zircon (a)	7	4	2	3
Zircon (b)	6	4	5	5
Zircon (c)	5	2	4	4
Zircon (d)			5	3
Zircon (e)	3	1	2	3
Zircon (f)	2	2	3	1
Zircon (g)	3	2		
Sphene			1	
Sillimanite		1		
Garnet	1	1	2	1
Monazite		2	1	
Xenotime		2		1
Epidote		1		
Brookite		2	1	
Anatase	2	3		
Chlorite		3	3	
Phlogopite			1	
Biotite			5	5
Fluorite			1	
Barite			1	
Collophane (?)				1

(1) Basal beds of lower member of Jasper Formation (Williams, 1958)
(2) Upper member of Jasper Formation
(3) Formation A

Symbols:
1. Less than 1%
2. 1-3%
3. 3-6%
4. 6-9 %
5. 10-15%
6. 15-25%
7. 25-40%
8. 40-70%
9. Greater than 70%

TABLE 4 (continued)

Tourmaline Classification (Williams, 1958, after Krynine, 1946)

Type I	Granitic; pleochroic, pink, green, brown; bubble inclusions common
Type II	Pegmatitic; pleochroic, bluish pink to blue, mauve, lavender; inclusions common to rare
Type III	Metamorphic; pleochroic in brown shades; carbonaceous inclusions common
Type IV	Authigenic; clear, overgrowths common
Type V	Sedimentary; rounded

Zircon Classification (Williams, 1958)

(a) Hyacinth to brown; sometimes pleochroic; well rounded to rounded; unoriented inclusions common

(b) Zoned; hyacinth to dark brown, sometimes pleochroic; more euhedral than type (a)

(c) Clear to pale hyacinth; well rounded to rounded; inclusions common

(d) Clear, occasionally pale hyacinth; subangular to subrounded; inclusions common

(e) Euhedral; clear to pale hyacinth; inclusions common

(f) Malacon type; opaque to sub-opaque

(g) Overgrowths; clear and hyacinth; hyacinth to brown cores; subangular

The conglomeratic and feldspathic sandstones of the upper and lower units are similar in composition, except for the differences mentioned above, to those of the lower member. The most noticeable sedimentary features in these two units are the abundant scour and fill structures and the lenticularity of the beds. Graded bedding and small-scale current bedding are particularly common in the higher beds of this member. Quartz is the cementing agent; welded grain contacts are abundant.

The middle unit of the upper member consists of interbedded pebble conglomerates, cobble conglomerates and medium- to coarse-grained feldspathic and conglomeratic sandstones. Lenticular, pinch-and-swell structures and small-scale crossbedding are much in evidence. Well rounded pebbles and cobbles are numerous; those up to 60 mm in diameter usually consist of quartz or chert, whereas the larger cobbles, locally as much as 100 mm in diameter, are composed of quartzite. In thin section this quartzite exhibits sutured contacts and abundant overgrowths.

In the heavy accessory mineral suite, tourmaline and zircon predominate, although biotite is also abundant; the latter mineral, together with muscovite, is commonly present as inclusions in the quartz pebbles. Metamorphic tourmaline is more abundant than in the lower member (Table 4); indicolite tourmaline is also present.

The heavy mineral separation process yielded a quantity, amounting to over 75 per cent of the total recovery, of a granular material with a refractive index of only 1.562; only the rims of the grains are transparent. It was concluded that this material is probably a mixture of various minerals, particularly illite, sericite, barite, chlorite and leucoxene, which form the "sericite" matrix observed in thin section. Its opacity is presumably due to the lack of orientation of its components. It was not included in the heavy mineral count. Although the

opaque heavy minerals were not investigated, an abundance of lodestone was noted in the sample studied.

Formation A

General

Only the lower part of Formation A was examined. The basal beds consist mainly of feldspathic and quartzitic sandstones and quartzites. They are usually very well sorted, mostly medium-grained, with infrequent thin pebbly bands. They grade upward into dense, hard quartzites, composed entirely of quartz grains, and quartzite and chert rock fragments. The cementing material in these beds is quartz; overgrowths and welded grain contacts are very common. The quartzites are overlain by a prominent argillaceous unit which occurs some 700 feet above the base of the formation (Table 3). Microcline feldspar occurs in abundance in some sandstone beds near the top of this unit.

A sample from Formation A yielded a heavy mineral suite similar in most respects to that from the upper member of the Jasper Formation, except for the greater quantity of metamorphic tourmaline. Opaque matrix material was also present in large amount.

Age

Since the apparently conformable Miette-Jasper succession in this area has proved non-fossiliferous, the Cambrian-Precambrian boundary has to be drawn on lithological grounds. In much of the Rocky Mountain region, recessive, poorly sorted arenaceous and argillaceous rocks, similar to those of the Miette Formation, are placed in the Precambrian, whereas cliff-forming, clean, well sorted sandstones and quartzites are usually assigned to the Cambrian (e.g. Mountjoy, 1962). R.E. Greggs (personal communication) considers that fossiliferous equivalents of

Formation A are Cambrian in age. Mountjoy (1962), in describing the stratigraphy of the Gog Group, has reported that a carbonate and argillaceous unit towards the top of this group is the apparent equivalent of the Olenellus-bearing Tah (Mural) Formation of the Mount Robson District, and that this unit contains abundant Archaeocyathids, except in the Chetamon thrust sheet. He further states that Archaeocyathids and Scolithus tubes occur in about the upper 1000 feet of the Gog Group at several localities. Since the Jasper Formation forms the lower part of the cliff-forming arenaceous succession of the Gog Group, the Cambrian-Precambrian contact is here placed at the base of this formation.

Depositional Environment

The dominantly argillaceous nature of late Miette sediments reflects a relatively quiet marine environment of deposition in waters of moderate to shallow depth (Charlesworth et al., 1961, p. 10). The considerable argillite content of the sediments in the lower member suggests similar conditions at the beginning of Jasper time, although the facies variations present may indicate either local downwarping or irregularities in topography, resulting in the formation of basins of varying depth, or variations in the strength and direction of longshore currents producing selective deposition of sediment, or a combination of both. The presence of argillite phenoclasts, and the lack of very fine detrital material, in these beds might be attributed to the work of such currents. On the other hand, the considerable thickness of sediments, the abundance of scour-and-fill structures, the relative scarcity of crossbedding, and the coarse-grained nature of the sediments indicate that during most of Jasper time sedimentation was taking place rapidly in shallow marine waters in a subsiding basin. During Formation A time conditions were not much different, though the clean, very well-sorted nature of the sediments, together with the presence of some crossbedding, indicate that winnowing by currents must have been more prevalent then.

Provenance

The gross lithology of the Jasper Formation differs markedly from that of the Miette. The reasons may be several, viz: (1) reduction in water depth as a result of basin infilling, or (2) marked climatic changes favouring increased rate of erosion, or (3) either uplift of the old source area, or the appearance of a new source terrain. Limited information provided by a few outcrops of crossbedded sandstone indicate the source terrain lay to the east or northeast. This is in accord with observations by Mountjoy (1962), who stated, with respect to the Gog Group: "Current bedding is also abundant in the lower part of the group, and the persistent southwest dips of these structures in the area studied are suggestive of a southwesterly direction of transport." The subangular to subrounded shape of most of the granules and many of the pebbles, the large cobbles in the upper member, and the generally coarse-grained nature of the rocks, are indicative of a short distance of transport. The abundance of microcline feldspar granules and pebbles, most of which have suffered comparatively little weathering, may indicate that the time of transport was also short.

Several lines of evidence throw some light on the nature of the source terrain. First, the coarse, conglomeratic character of the sediments, the large cobbles in the upper member, the abundance of microcline feldspar, and the abundant scour-and-fill sedimentary structures, suggest high relief and consequent rapid rate of erosion. Secondly, the presence of relatively large inclusions of biotite and muscovite in the quartz pebbles, and the lack of liquid or other inclusions typical of igneous quartz, the abundance of chert and of "stretched" quartzite, and, rarely, schistose rock fragments, and the presence of quartzite cobbles in which the quartz grains have developed overgrowths (indicating a second cycle of sedimentation), imply a metamorphic source terrain. The relative abundance of

metamorphic tourmaline is additional evidence in this regard; the presence of indicolite tourmaline, however, strongly suggests the presence of pegmatite bodies as well. Thirdly, the dominance of quartz and microcline feldspar, together with the presence of ultrastable heavy accessory minerals, is significant, suggesting that the less stable minerals such as plagioclase, together with fine argillaceous material, may have been removed during an earlier cycle of sedimentation.

The foregoing might reasonably be interpreted as evidence that the Jasper sediments were derived from a largely metasedimentary source terrain, probably cut by pegmatite intrusives, which had not been eroded sufficiently to expose deep seated igneous or high-grade metamorphic rocks to any great extent. The cleaner, better sorted sediments of Formation A suggest that reduction in relief of the source terrain, or a change in climatic conditions, resulted in a slower rate of sedimentation with consequently more effective winnowing action by shore currents.

STRUCTURE OF THE PYRAMID LAKE MAP-AREA

Introduction

The greater part of the Pyramid Lake map-area is underlain by the Jasper Formation. Exposures are confined to the periphery, and to the vicinity of Katrine Lake (Figure 3). Local stratigraphic control is poor, owing to the monotonous nature of the formation. As a result, the structure of the map-area to be described below is largely hypothetical.

The Pyramid thrust fault defines the northeastern boundary of the map area (Figure 5), its trace extending from the canyon of Pyramid Creek just west of the railway, westward along the north shore of Pyramid Lake as far as the base of Pyramid Mountain, and thence northward and westward around the base of the mountain. Along the thrust Cambrian rocks are brought into contact with Devonian in the eastern part of the map area, and with Mississippian rocks in the vicinity of Pyramid Mountain. The fault trends about N 60W and dips southward at about 70 degrees near the railway, but flattens to a gentle westward dip on Pyramid Mountain (see Collet, 1932, Figure 2).

The nature of the deformation within the Pyramid thrust-sheet varies considerably. Generally speaking, the Jasper Formation and Formation A have behaved as a single, very competent structural unit, and have been deformed into relatively simple folds of large size. The Jasper Formation and Formation A on the slopes of Pyramid and Kinross mountains lie on a limb of one of these folds. Such folds contrast markedly with the much more intense, smaller-scale folding in the underlying, less competent, Miette and Old Fort Point Formations (see e.g. Charlesworth et al., 1961, Plate 1).

However, near the Pyramid thrust fault, for example within the Pyramid Lake map-area, the Jasper Formation has experienced very complex folding and faulting on a scale much smaller than is the case away from the fault.

Faulting and Folding

The major structural feature is the Katrine Lake syncline (Figure 5). The trace of the axial surface of the syncline has a trend ranging from N 60W near Pyramid Lake, to N 80W near Katrine Lake, and to N 70W in the eastern part of the area. The dip of the axial surface is unknown. The hinge of the syncline probably plunges gently eastward, as is indicated by the divergence in attitude between the two limbs. The southern limb, which is also the northern limb of the Jasper anticline (Charlesworth et al., 1961), is well defined by the northward-dipping beds which underlie the prominent ridge extending from Pyramid Lake eastward to the railway. The northern limb is not nearly as well displayed and is complicated by much minor folding.

The syncline is cut by two major thrusts, the one to the north striking N 85W, and that to the south about N 85E; the dips are not known but are assumed to be moderate, i.e. about 30 degrees. Numerous other thrust faults probably occur. In the bed of Pyramid Creek, for example, several such faults, dipping steeply to the south, may be seen in the vicinity of the Pyramid thrust, and appear to terminate against it. The syncline is also cut by a number of transcurrent faults, the strikes of which range from N 15E to N 60E; the dips are not known, but are assumed to be either vertical or steeply inclined. The movements along these faults have probably had strike-slip, as well as dip-slip, components. This is suggested by the displacement of the steeply dipping basal beds of the Jasper Formation along the southern boundary of the map-area. The thrusts may terminate against these transcurrent faults, or vice versa. It appears likely that folding, thrust-faulting, and transcurrent faulting all took place more or less contemporaneously, the transcurrent faults separating the Katrine Lake syncline into segments with different structural configurations.

Jointing and Fracturing

During the course of field mapping over 1200 attitudes of joints, faults, and fractures were recorded. Some of these have been plotted on the map of Figure 4. Numerous steeply dipping fractures or joints, striking more or less at right angles to the fold trends, and consequently more or less in the direction of maximum compressive stress, are common in the western half of the map area; fracturing and brecciation along the bedding are also of common occurrence. A system of steeply dipping conjugate fractures, probably associated with shortening in the northeast-southwest direction, is well developed in the southeastern part of the map-area.

To determine what other significant patterns might be present, the map-area was divided into seven areas, each of which appeared to form a reasonably coherent tectonic unit. The poles to the joint and fracture planes in each were plotted on a Schmidt equal-area net, utilizing I.B.M. 1620 computing techniques recently developed for investigations of this type (Muecke, 1964). The resulting diagrams, contoured to show pole density in terms of the percentage of poles per 1 per cent of area, have been reproduced in Figure 4. The diagrams for Areas 1, 2 and 3, show clearly the joint sets at right angles to the structural trend, and those approximately parallel to the bedding dip. Concentration maxima in the other diagrams are not so pronounced; those in Area 5 are more apparent than real due to the small number of observations.

Discussion

At first sight the shortening in the comparatively open-folded Jasper Formation - Formation A unit appears to be considerably less than that in the relatively incompetent, tightly-folded Precambrian rocks. If such a discrepancy actually exists, either the deformation of the late Precambrian beds took place before the deposition of the Cambrian strata, or the Precambrian - Cambrian

boundary follows a major bedding thrust. However, the absence of any angular unconformity or major thrust at the base of the Jasper Formation suggests that the apparent discrepancy in shortening between the two units is illusory, and results from differences in the behaviour of the two units during the Laramide orogeny.

Movement along the Pyramid thrust may have occurred contemporaneously with deformation of the rocks in the Pyramid Lake map-area, or it may have developed only after considerable deformation had occurred. The latter possibility is suggested by the divergence in trend between the Pyramid thrust and the smaller thrusts in the map-area, this divergence being attributed to anticlockwise rotation along the Pyramid thrust, which is known to die out a short distance northwest of Pyramid Mountain (Mountjoy, 1961). Rotation of structural elements in the underlying Precambrian, due to movement along the Pyramid thrust, has been suggested by Evans (1961). The folding of the Pyramid thrust, like that of other major thrusts in the Rocky Mountains (e.g. Ziegler, 1960; Charlesworth, 1961) may have occurred towards the end of the period of deformation.

METAMORPHISM AND VEINING

Veining in the Jasper arenites is relatively inconspicuous, whereas in the sandstones and conglomerates of the underlying Miette Formation it is a prominent feature. The veins that do occur are mainly restricted to sandstones at the base of the formation in the Pyramid Lake map-area. There they are commonly along small, discontinuous fractures associated with faulting. Quartz is the only vein material present. Very little veining was observed in exposures of the type section on Pyramid and Kinross mountains. The distribution of the veins suggests either that the vein quartz was derived from adjacent argillaceous rocks as the result of the activity of hydrothermal solutions, or that the relatively impermeable argillaceous layers in some way controlled the precipitation from circulating solutions.

Metamorphism of the rocks in the Jasper Formation is either nonexistent or of very low grade. Chlorite is present in the argillaceous beds, but there are no diagnostic metamorphic minerals in the arenaceous beds. The high degree of induration of the latter is due to silica cement, the abundance of welded contacts suggesting that pressure-solution played an important role. The greater induration of the quartzites of Formation A, as compared with that of the quartzitic sandstones of the Jasper Formation, may be ascribed to the essentially monomineralic character of these rocks; the increased number of quartz grain contacts would favour pressure-solution and cementation of the rock fabric. Similarly, the greater degree of induration of the Jasper Formation, as compared with that of the underlying Miette arenaceous rocks, probably results from the better sorting in the Jasper.

The virtual absence of plagioclase, which is so common in the Miette Formation, from the Jasper Formation is probably the result of its absence from the original sediment, rather than its destruction during metamorphism. The presence of potash feldspar in the Jasper Formation, on the other hand, and its absence from the Miette, may be explained on the basis of the difference in chemical enviroment

between the two formations. For example, the relative abundance of water in the more argillaceous Miette sediments would greatly favour the destruction of potash feldspar through hydrothermal alteration, with the resultant development of sericite or similar minerals.

CONCLUSIONS

Extensive exposures of the Jasper Formation occur in the vicinity of Jasper, Alberta. The formation forms a distinctive arenaceous succession, 1500 to 1700 feet thick, at the base of the Gog Group. It conformably overlies the Precambrian Miette formation, from which it may be distinguished chiefly by its dominantly arenaceous character, its better sorting, and by the virtual absence of feldspars other than microcline. It is conformably overlain by quartzites of Formation A of the Cambrian Gog Group, and may be differentiated from them by relatively poorer sorting, the abundant scour and fill structures, and the relative abundance of current bedding.

The type section is located on the eastern slopes of Pyramid and Kinross mountains. The formation is divided into two members: a lower member, 280 to 420 feet thick, consisting of conglomeratic sandstones with prominent beds of argillite and silty argillite, and an upper member, 1240 feet thick, composed largely of conglomeratic sandstones and pebble conglomerates in which scour-and-fill structures and current bedding are characteristic features. A destinctive cobble conglomerate, 120 feet thick, occurs near the middle of the upper member.

The Jasper formation is non-fossiliferous, but in view of the similar lithology of the rocks of Formation A and those of the Jasper, and of the stratigraphic position of the Jasper formation in the Gog sequence, it is thought to be of Cambrian age. The Cambrian-Precambrian boundary is therefore placed at the base of the formation.

The sediments of the Jasper Formation are considered to have been laid down in shallow marine waters. The source terrain, probably metasedimentary in nature, and possibly cut by pegmatite dykes, appears to have been located nearby, to the east or northeast of the basin of sedimentation.

Metamorphism of the Jasper sediments is of very low grade, the high degree of induration being due to cementation by silica cement. The lack of plagioclase feldspar is probably the result of the absence of this material in the source terrain, or of its destruction and loss during the transportation and sedimentation phases of the sedimentary cycle.

The extremely complicated structural conditions present in the Pyramid Lake map-area, on the very edge of the Pyramid thrust sheet, contrast markedly with the simple open folds seen in the area of the type section, although the rocks in both areas are located in the northeastern limb of the Jasper anticline. The synclinal structure present in the map-area is cut by a number of transcurrent and thrust faults. The marked divergence in the trend of the local structural elements, as compared with that of the Pyramid thrust fault, is probably the result of counter-clockwise rotation along the Pyramid thrust, a reasonable assumption in view of the fact that the Pyramid thrust is known to die out to the northwest of Pyramid Mountain.

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APPENDIX A

Thin Section Descriptions (refer Table 3)

P 5: Quartzite; quartz 68%, microcline 10%, rock fragments (quartzite and chert) 5%, matrix (sericite) 15%; grains 0.3 to 0.6 mm, max. 0.8 mm; mildly sutured contacts.

P 7: Quartzite; quartz (including quartzite) 98%, iron oxide 1%, matrix (sericite) 1%; highly brecciated, recrystallized; sutured contacts; undulatory extinction.

P 10: Quartzitic sandstone; well sorted, very fine-grained (mostly less than 0.2 mm, occasionally to 0.8 mm); quartz 88%, microcline 5%, rock fragments (quartzite, chert) 2%, matrix (sericite) 5%, muscovite tr.; fractures filled with crushed quartz; grains angular to subangular, some subrounded; strain shadows common, welded to mildly sutured contacts.

P 14: Quartzite; mostly fine-grained (0.3 to 1.0 mm); quartz 65%, rock fragments (quartzite, chert) 7%, microcline 22%, matrix 5%, traces muscovite, chlorite, monazite (?), and pyrite; some quartz overgrowths, undulatory extinction; strain lamellae, welded and sutured contacts.

P 18: Siltstone; quartz (including quartzite) 68%, microcline 10%, matrix (white mica, sericite) 20 to 30%, muscovite 3%, zircon tr., dravite tourmaline tr.; grains 0.1 to 0.2 mm, occasionally to 3 mm; some overgrowths and welded contacts, strain shadows and Boehm lamellae.

P 23: Arkose; poorly sorted, about 50% of grains 0.1 mm or less, remainder 0.5 to 1.5 mm, a few large grains (microcline) to 5 mm; quartz 59%, microcline 25%, rock fragments (quartzite, chert) 5%, muscovite 1%, matrix (sericite) 10%; much metasomatic replacement of microcline by high Ab sodic plagioclase (?) in optical continuity with the microcline; quartz grains fractured, with strain shadows, welded contacts.

P 30: Sandstone; fine-grained (0.1 to 0.2 mm, max. 2 mm), grains subangular; quartz 57%, rock fragments (chert, quartzite) 10%, white mica 1%, microcline 15%, traces goethite, biotite (as inclusions), zircon.

P 37: Sandstone; grains 0.2 to 0.5 mm, reaching 2 mm, subangular to subrounded; quartz 67%, rock fragments (chert, quartzite) 15%, microcline 7%, matrix (sericite and white mica) 10%, white mica 1%, traces dravite tourmaline, zircon (as inclusions); some incipient sutured contacts, some strain lamellae.

P 38: Siltstone; very fine grained (less than 0.1 mm, occasionally to 0.5 mm); quartz 40%, rock fragments (quartzite) 5%, microcline 10%, white mica 5%, matrix (sericite and white mica) 40%, traces chlorite, brown zircon; some quartz grains elongated; Boehm lamellae and strain shadows common.

P 40: Pebbly sandstone; grains 0.3 to 0.5 mm, some to 8 mm, larger grains rounded to subrounded; quartz 55%, rock fragments (microcrystalline quartz, chert, siltstone) 20%, microcline 15%, matrix (quartz grains, sericite) 10%, traces biotite (as inclusions), muscovite and magnetite.

P 50: Sandstone; grains mostly about 0.5 mm, some larger rounded grains to 5 mm; quartz 66%, rock fragments (quartzite) 20%, microcline 7%, goethite 2%, matrix (sericite) 5%, quartz grains show strain lamellae, welded contacts.

P 59: Feldspathic quartzite; grains mostly 0.2 to 0.5 mm, occasionally to 5 mm, subrounded to subangular, fractured; quartz 72%, rock fragments (quartzite, chert) 7%, microcline 15%, muscovite 1%, matrix (sericite) 5%, traces ilmenite, leucoxene; quartz grains have strain shadows welded contacts, Boehm lamellae.

P 70: Pebbly sandstone; angular to subangular grains 0.2 to 0.5 mm, but rounded grains 5 to 10 mm predominate; quartz 25%, rock fragments (quartzite and microcline) 50%, microcline 20%, matrix (sericite, quartz) 4%, muscovite 1%, traces biotite (as inclusions) and zircon.

P 79: Sandstone; subangular grains mostly 0.5 mm, but many (well rounded) to 5 mm; quartz 63%, rock fragments (mosaic quartz and quartzite, chert)15%, microcline 15%, matrix (sericite) 5%, muscovite 2%, traces goethite, magnetite; welded contacts common; some biaxial quartz (strained).

P 87: Quartzite cobble; fine-grained (0.1 to 0.3 mm); quartz 84%, rock fragments (chert, siltstone, quartzite) 10%, microcline 5%, matrix (white mica) 1%, trace magnetite; quartz overgrowths very common.

P 93: Sandstone; poorly sorted, very coarse grained, pebbles to 10 mm predominate, with smaller grains 0.5 to 1 mm; quartz 25%, rock fragments (quartzite, mosaic quartz, siltstone) 27%, microcline 8%, matrix (sericite, chlorite, white mica, quartz) 40%.

P 101: Sandstone; grains average 0.5 mm, range 0.1 to 3 mm, poorly sorted; quartz 69%, rock fragments (quartzite and chert(?)) 15%, microcline 10%, matrix (sericite) 6%.

P 113: Sandstone; fine grained (grains 0.1 to 0.2 mm, abundant to 1 mm, occasionally to 5 mm; mostly subangular); quartz 75%, rock fragments (quartzite, chert) 15%, microcline 5%, matrix (sericite, white mica, chlorite(?), quartz) 5%, traces white mica, biotite (as inclusions), chlorite (as inclusions); welded contacts common, strain lamellae present.

P 114: Siltstone; very fine grained (less than 0.1 mm), angular to subangular; quartz 55%, microcline 5%, matrix (sericite and chlorite) 40%, traces goethite, muscovite, zircon (both detrital and as inclusions), apatite, rutile (as inclusions); some welded contacts.

P 121: Sandstone; medium-grained (angular grains 0.1 to 0.5 mm, rounded grains to 3 mm); quartz 60%, rock fragments (largely metamorphic quartz) 20%, microcline 8%, muscovite (as inclusions in quartz) 2%, matrix (sericite) 10%, quartz grains biaxial in part, with undulatory extinction, sutured contacts.

P 131: Sandstone; grains mostly 0.2 to 0.5 mm; quartz 50%, rock fragments (metamorphic quartz, microcrystalline quartz or chert) 30%, microcline 15%, matrix (sericite) 3%, phlogopite and muscovite 2%; strain shadows, incipient suturing; checkerboard(?) twinning in microcline.

P 140: Arkose; coarse-grained (0.5 mm but many grains to 5 mm); quartz 35%, rock fragments (quartzite, chert) 25%, microcline 35%, matrix (sericite, chlorite) 5%; quartz pebbles with overgrowths, internal sutures.

P 152: Sandstone; very fine-grained (grains 0.1 mm average, max. 0.5 mm), angular; quartz 80%, microcline and rock fragments (quartzite, chert) 10%, matrix (sericite, chlorite (?), white mica(?), quartz) 10%, tourmaline tr.; strain shadows, Boehm lamellae, common; some welded contacts, incipient suturing, overgrowths.

P 157: Silty argillite; angular grains less than 0.1 mm; quartz 34%, microcline 3%, muscovite and chlorite 10%, magnetite and leucoxene 2%, matrix (sericite, chlorite) 50%, traces brown zircon, green tourmaline.

P 160: Sandstone; very fine-grained, grains angular, 0.3 mm; quartz 85% microcline 10%, siderite 2%, matrix (sericite, quartz) 2%, magnetite 1%, traces muscovite, pyrite; sutured contacts common, some biaxial quartz; siderite associated with microcline.

P 170: Sandstone, conglomeratic; grains mostly 0.3 to 0.5 mm, but abundant to 4 mm; quartz 70%, microcline 10%, rock fragments (quartzite) 15%, muscovite (in part as inclusions) 3%, matrix (sericite, muscovite, quartz) 2%; much brecciation; quartz grains with welded contacts, incipient suturing, some overgrowths, strain lamellae.

P 182: Arkose; grains 0.3 to 0.5 mm, occasionally 1 mm; quartz 35%, microcline 50%, rock fragments (quartzite) 5%, siderite and goethite 5%, matrix (sericite) 5%; siderite and goethite associated with the microcline; quartz overgrowths common.

P 183: Sandstone; angular to subangular grains 0.1 to 0.5 mm, but many to 2 mm; quartz 79%, microcline 8%, rock fragments (quartzite, chert) 5%, siderite and goethite 5%, matrix (sericite) 3%, traces calcite, chloritoid(?), muscovite (as inclusions); siderite and goethite mostly associated with microcline.

P 184: Silty argillite; grains less than 0.05 mm; quartz 39%, microcline 5%, muscovite 3%, chlorite 10%, leucoxene 3%, matrix (chlorite and sericite) 40%; quartz grains angular to subangular.

P 190: Argillite; very fine-grained; quartz and K feldspar 40%, matrix (chloritic) 60%.

P 191: Argillite; very fine-grained; quartz (angular) and feldspar(?) 30%, muscovite and chlorite 10%, matrix (chloritic) 60%.

P 195: Arkose; poorly sorted, grains 0.1 to 3 mm; quartz 40%, microcline 40%, rock fragments (quartzite) 19%, matrix (sericite) 1%, trace sphene (zircon ?); quartz overgrowths common.

P 204: Sandstone; grains 0.3 to 0.5 mm, occasionally to 1 mm, banded; quartz 82%, microcline 7%, rock fragments (quartzite) 5%, matrix (sericite) 8%, traces muscovite (as inclusions), magnetite and zircon(?) (as inclusions); welded contacts common; strain shadows in both quartz and microcline.

P 208: Siltstone; angular to subangular grains 0.1 mm or less; quartz 68%, microcline 5%, rock fragments (chert) 5%, muscovite 2%, matrix (sericite) 20%, traces zircon and tourmaline; quartz overgrowths, welded contacts, incipient sutures.

P 213: Quartzite; grains 0.3 to 0.7 mm, some rounded grains to 2 mm; quartz 100%, traces leucoxene(?), zircon (as inclusions), dravite tourmaline; overgrowths, incipient suturing, welded contacts very common.

P 218: Quartzite; banded; two size ranges of grains, 0.1 to 0.2 mm and 0.5 to 0.8 mm; quartz 97%, rock fragments (quartzite, chert) 3%, traces leucoxene(?), green tourmaline, zircon, muscovite; overgrowths, incipient suturing, strain shadows common.

F 226: Quartzite; grain size range 0.1 to 1 mm; quartz 98%, rock fragments (quartzite) 2%, traces zircon, muscovite; fractured; overgrowths, strain shadows common; marked internal sutures in quartzite grains.

P 230: Quartzite; angular to subangular grains 0.3 to 1 mm; quartz 95%, rock fragments (quartzite, chert) 5%; traces sphene(?) (as inclusions), green tourmaline, zircon, biotite (as inclusions); overgrowths common, some incipient suturing.

P 241: Siltstone; angular to subangular quartz and feldspar grains 0.02 to 0.05 mm; quartz 45%, microcline 5%, chlorite 10%, matrix (chloritic) 40%, traces zircon, tourmaline, biotite, muscovite.

P 243-1: Sandstone; subangular to subrounded grains mostly 0.1 mm, some to rounded grains 1 mm; quartz 65%, microcline 10%, siderite 2%, matrix (sericite) 23%; traces rutile(?) (as inclusions), dravite tourmaline; some overgrowths and welded contacts.

P 243-2: Sandstone; very fine grained, but some rounded grains to 2 mm; quartz 55%, microcline 20%, matrix (sericite) 25%.

PYRAMID LAKE

KATRINE LAKE

ATHABASCA RIVER

TRAIL

ROAD

C.N. RAILWAY

HIGHWAY

N

LEGEND

- ARGILLITE, SILTSTONE AND SANDSTONE
- COBBLE CONGLOMERATE
- CONGLOMERATIC SANDSTONE
- QUARTZITE
- CARBONATE
- BEDDING ATTITUDE, DIPPING 5 DEGREES
- BEDDING ATTITUDE, VERTICAL
- ROAD
- TRAIL
- RAILWAY
- SWAMP
- OUTCROP

SCALE

0 500 1000 1500 2000

FEET

PYRAMID LAKE MAP AREA

OUTCROPS

LITHOLOGY & BEDDING ATTITUDES

FIGURE 3

PYRAMID LAKE

KATRINE LAKE

ATHABASCA RIVER

TRAIL

ROAD

TRAIL ROAD

RAILWAY

C.N. RAILWAY

HIGHWAY

1

2

3

4

5

6

7

170 MEASURMENTS

117 MEASURMENTS

248 MEASURMENTS

71 MEASURMENTS

266 MEASURMENTS

210 MEASURMENTS

161 MEASURMENTS

50-60

60-90

LEGEND

- ARGILLITE AND SILTSTONE
- COBBLE CONGLOMERATE
- CONGLOMERATIC SANOSTONE
- QUARTZITE
- CARBONATE
- 80 — JOINT OR FRACTURE DIPPING 80 DEGREES NORTHWEST
- JOINT OR FRACTURE, VERTICAL
- BRECCIATION
- AREA BOUNDARY

CONTOURED DIAGRAMS SHOW PERCENTAGE OF POLES TO JOINT PLANES ON WULFF NET PER 1 PER CENT AREA

SCALE

0 500 1000 1500 2000 FEET

PYRAMID LAKE MAP AREA

TECTONIC DATA

JOINTS AND FRACTURES

(Lithology from Figure 3)

FIGURE 4

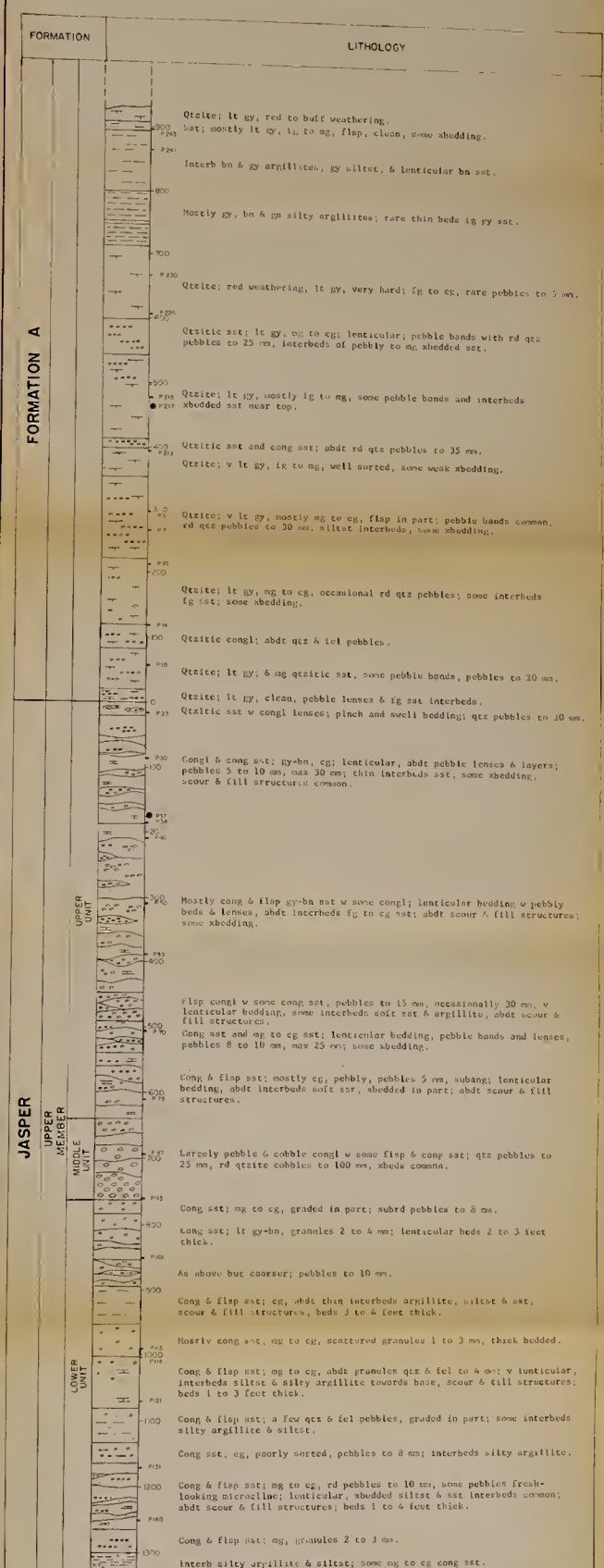
PYRAMID LAKE MAP AREA
STRUCTURE & STRATIGRAPHY
FIGURE 5
N
A
A'
B
B'
PYRAMID FAULT
KATRINE LAKE
KATRINE LAKE SYNCLINE
ATHABASCA RIVER
C N RAILWAY
PYRAMID LAKE
U
D
?
LEGEND
PALEOZOIC
FORMATION A
JASPER FORMATION Middle unit of upper member
JASPER FORMATION— Upper and lower units of the upper member and upper beds of lower member (undifferentiated)
JASPER FORMATION Basal beds of lower member
MIETTE FORMATION
KATRINE LAKE SYNCLINE
ANTICLINE (VISIBLE)
ANTICLINE (INFERRED)
SYNCLINE (VISIBLE)
SYNCLINE (INFERRED)
FAULT (TRANSCURRENT)
FAULT (THRUST)
CONTACT (VISIBLE)
CONTACT (INFERRED)
SCALE
0 500 1000 1500 2000
FEET

STRUCTURE SECTIONS
(REFER FIGURE 5)
SCALE 1:50000
FIGURE 5A
SECTION A-A'
SECTION B-B'
KATRINE LAKE SYNCLINE
PYRAMID FAULT
SOUTHWEST
NORTHEAST
DEPTH IN FEET
4500
4000
3500
3000
LEGEND
PALEOZOIC
JASPER FORMATION (Middle Unit of Upper Member)
JASPER FORMATION (Upper and Lower Units of Upper Member and Upper Beds of Lower Member - Undifferentiated)
JASPER FORMATION (Basal beds of Lower Member
MIETTE FORMATION

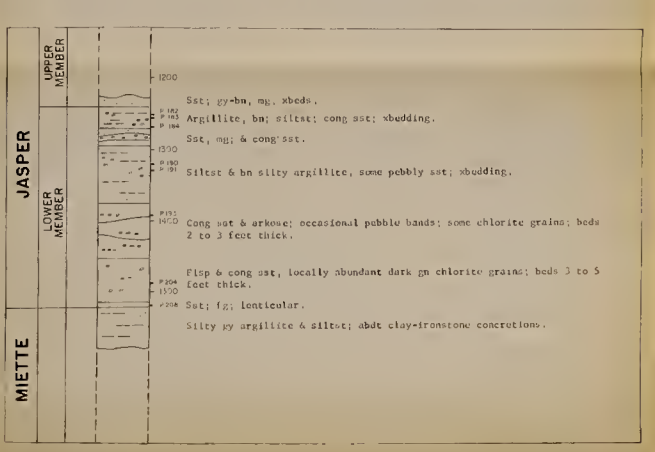
JASPER FORMATION

SCALE: 1" = 100'

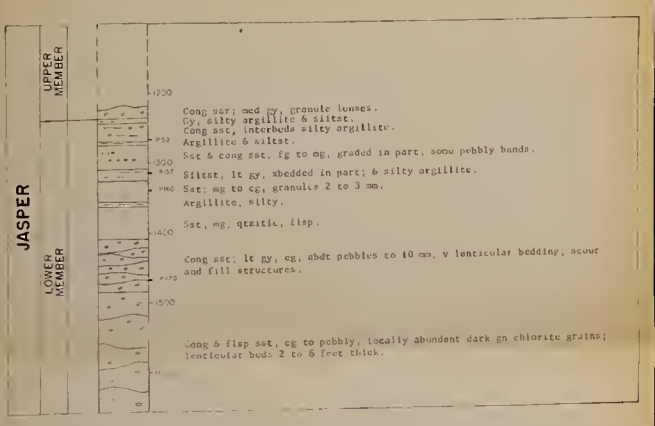
PYRAMID A TYPE SECTION



KINROSS SUPPLEMENTARY TYPE SECTION



PYRAMID B SUPPLEMENTARY SECTION



LEGEND

Lithology :

- Quartzite
- Sandstone
- Conglomeratic sandstone
- Conglomerate
- Cobble conglomerate
- Siltstone
- Argillite
- Siltstone interbeds
- Sandstone interbeds
- Silty argillite
- Lenticular bedding, scour and fill structure
- Lenses (conglomerate)

Abbreviations

abdt	abundant	gy	grey	siltst	siltstone
bn	brown	interb	interbedded	subang	subangular
cg	coarse-grained	lt	light	subrd	subrounded
cong	conglomeratic	med	medium	v	very
congl	conglomerate	mg	medium grained	w	with
fel	feldspar	qtz	quartz	xbedded	crossbedded
fg	fine-grained	qtzite	quartzite	xbedding	crossbedding
flsp	feldspathic	qtzitic	quartzitic	8 mm	8 mm in diameter
gn	green	rd	round		

Other

- Thin Section
- Heavy Mineral Analysis

B29821